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A STUDY OF ALTERNATIVE CONCEPTS
FOR PROVIDING A LAKE MICHIGAN FERRY SERVICE

EXECUTIVE SUMMARY

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Transportation
Research Institute

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EXECUTIVE SUMMARY

I. INTRODUCTION.

This study was sponsored by the Michigan Transportation Research Program (MTRP), a consortium of academic and business resources in Michigan organized to assist the State Government in formulation of transportation research, development and demonstration programs.

For several years, the railroads operating rail car ferries across Lake Michigan have been experiencing continuing declines in their rail car transit movements. The railroads have each individually petitioned the regulatory authorities to allow abandonment of their ferry service, claiming that the operations are losing money, and are no longer needed. The State, for its part, has resisted the demands claiming that removal of the service would cause severe economic damage to the area.

Recent studies by the Michigan Department of State Highways and Transportation (MDSH&T) recommended that the State preserve all of the rail car ferries except one (the Grand Trunk and Western).¹ Such preservation would require significant state financial support.

The Quadrant Committee of the Michigan Legislature recommended to the MTRP that a preliminary study be conducted that would evaluate alternative designs of ships that could be utilized in maintaining the ferry service. The paper would deal with the cost, reliability, and travel time characteristics of the alternatives. The results would be used to further expand the Legislature's knowledge of all available options as it makes its decision on the future of the Lake Michigan car ferries.

1. Lake Michigan and Mackinac Straits Car Ferry Services, Task 4, Agreement No. 75-1063. Michigan Department of State Highways and Transportation. 1975.

An early planning decision was that an examination of alternative ship designs would require that the evaluations be performed on the basis of segmented services. Thus, the following classes of service were separately considered:

<u>Service</u>	<u>Attributes Most Important</u>
rail	cost, flexibility
truck	cost, frequency, reliability
truck-trailers	cost, reliability, schedule
passenger-auto	frequency, speed, schedule

II. STUDY ASSUMPTIONS.

A series of assumptions were made concerning the environment in which the ferries would operate. These assumptions pertained to: (1) traffic volumes, seasonability, and direction; (2) vehicle dimensions and weights; (3) routes, including trip distances, etc.; (4) annual and daily operating profiles; and (5) financial considerations.

A. Traffic Volumes, Seasonability and Direction.

A recent study by the Wisconsin-Michigan Bi-State Task Force estimated a market of one million passengers and 300,000 vehicles per year. Those estimates were used in this study. Additionally, it was estimated that 30,000 trucks per year would also utilize the "convertible" ships, i.e., vessels designed to accommodate passengers, automobiles, and trucks.

On vessels that were designed for a truck-oriented service, the estimated annual traffic volume was placed at 50-100,000 passengers and 50,000 trucks.

Rail traffic was estimated at 45,000 cars/year, which is about equal to the total movements in 1973 over the C & O and Ann Arbor routes.

Reliable forecasts of the traffic seasonal variations were not available; therefore, the vessels were evaluated on the basis of their capabilities for handling seasonal fluctuations. The degree of seasonal capacity increase potential was represented by the ratio of maximum daily capacity to the assumed average daily volume.

It was assumed that flows would be equal in each direction.

B. Vehicle Dimensions and Weights.

The following weights and dimensions were used:

rail car:	coupled length	60 ft. (avg.)
	req'd width	12 ft. (max.)
	overhead	20 ft. (max.)
	gross weight	224,000 [#] (max.)
automobiles:	weight	3500 [#] (avg.)
	lane width	10 ft.
	lane length	18 ft.
	overhead clearance	8 ft.
trucks:	weight	55,000 [#] (avg.)
	lane width	12 ft.
	lane length	55 ft.
	overhead clearance	15 ft.
passengers:	weight (incl. luggage)	240 [#]
	enclosed deck area req'd	25 ft. ² (per person)
	exterior deck area req'd	25 ft. ² (per person)
	clear height	7.5 ft.

C. Routes.

The principal route considered in the design and economic analysis had the following characteristics:

one way distance (entrance-to-entrance)	60 stat miles
harbor transit and maneuvering delay, per call	20 minutes
maximum vessel length	450 feet
maximum draft	18 feet

The above routes correspond to either Ludington-Manitowoc or Frankfort-Kewaunee.

D. Operating Profile.

For normal operations, a 12-18 hour per day schedule was envisioned. For the displacement vessels, this corresponds to two round-trips per day on the 60 stat mile route. For the high-speed, air cushion vehicles, there were four round trips per day assumed.

All schedules assumed one-hour-turnaround time per call, including approximately 20 minutes for harbor transit and reduced speed, maneuvering, docking and undocking. It is obvious that the requirement of a quick turnaround for a large number of vehicles can be met only by simultaneous loading and unloading, with the passengers doing their own driving.

The vessels were assumed to operate on their normal schedules year round. For all vessels, a preliminary estimate of 345 working days per year has been made. Of the remainder, 10 days were set aside for layup, and 10 days for weather and ice.

E. Financial Assumptions.

The annual cost of capital recovery was based on the following:

- capital investments were made with cash.
- corporate income tax of 48 percent.
- tax deferral was assumed, with an economic life of 35 years for conventional vessels, and 15 years for air cushion vehicles.
- an after-tax yield on investment of 10 percent was specified.

Only the usual items of vessel operating cost were included in the analysis. Specifically excluded were direct operating costs associated with maintenance and operation of the shore facilities.

III. VESSEL CONCEPTS EVALUATED.

The vessel types evaluated in the study were:

- conventional monohull displacement vessels,
- integrated tug-barge combinations (ITB),
- air-cushion vehicles (ACV), and surface-effect ships (SES),
- multi-hull (i.e., catamaran) vessels, and
- hydrofoil craft.

Investigations of the last two concepts (multihull and hydrofoil craft) were dropped early in the study because of inherent ice-breaking deficiencies with these types of craft. Full-year operating capability was considered to be an essential requirement.

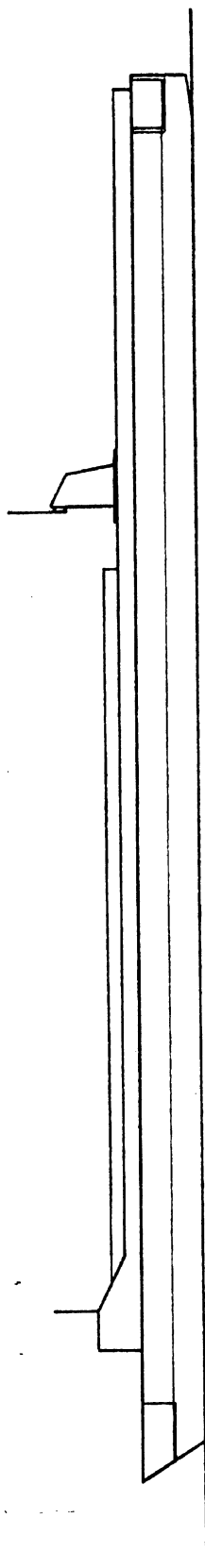
Figure 1 shows the comparative profiles of the final vessel designs that were given definitive evaluation.

A. Highway Vehicle and Passenger Vessels.

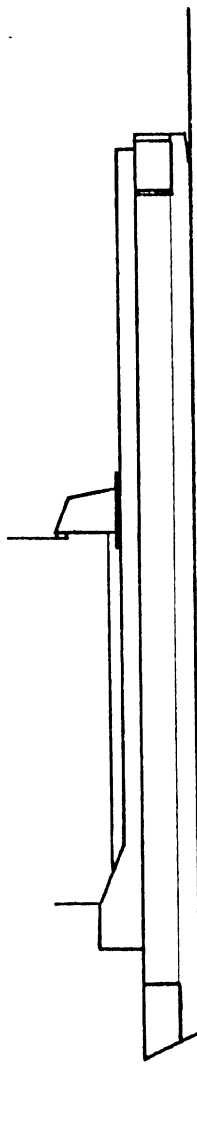
1. Conventional Displacement Ships.

There were several features common to all conventional displacement craft regardless of the design:

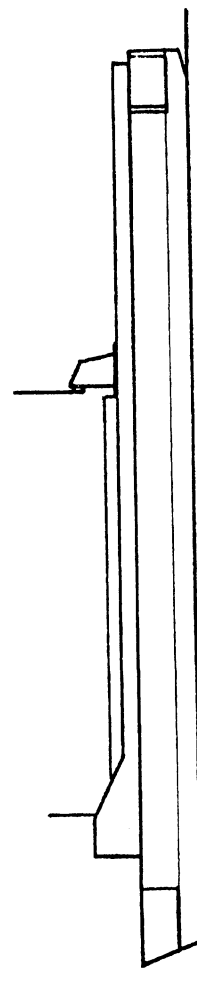
- day-boat arrangement of passenger accommodation,
- drive-through arrangement of vehicle spaces,
- sophisticated automation systems for engine-room operations,
- active fin stabilization,
- ice transiting capability, and
- vessel maneuverability.



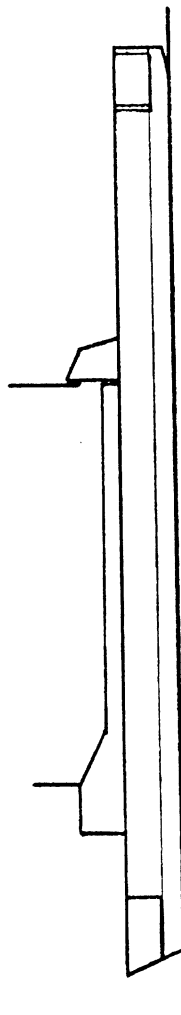
Design I: 28.5-knot highway/passenger ferry.



Design II: 26-knot highway/passenger ferry, 2-ship service.

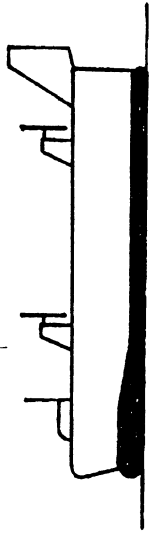


Design IIS: 21-knot highway/passenger ferry.

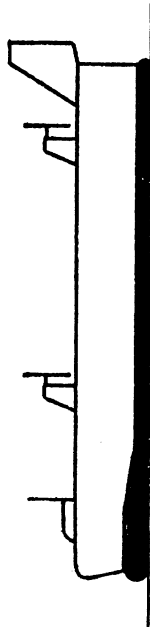


Design IIT: 21-knot truck ferry.

Fig. 1. Comparative profiles of conceptual vessel designs (scale: 1 in = 100 ft). (Continued)



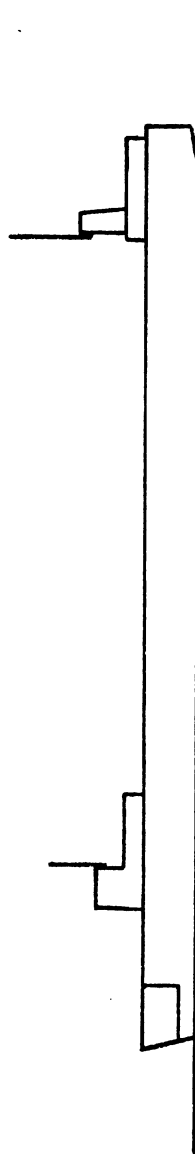
Design A: 600-ton ACV.



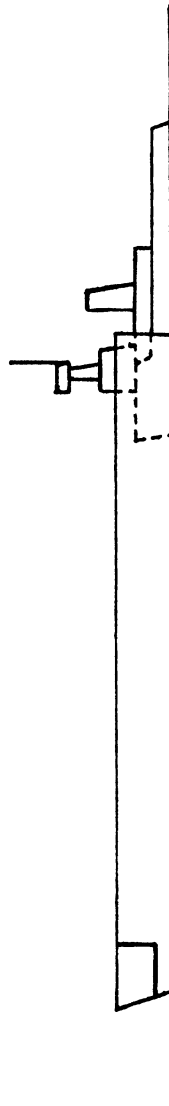
Design B: 700-ton ACV.



Design C: 300-ton ACV.



Rail ferry: 38-car conventional vessel, 16-knot.



Rail ferry: 30-car integrated tug/barge combination, 16-knot.

Fig. 1. (continued.)

Four conventional displacement designs were considered:

Design I -- 28.5 knot auto/passenger/truck ferry, sized to handle the entire specified traffic volume with a single vessel. Vessel exceeded desired length maximum, and was not evaluated further.

Design II -- A 26-knot ferry designed for two-ship service.

Design IIS -- A derivative of Design II, but with reduced speed to 21 knots.

Design IIT -- A simplified version of Design IIS, with the convertible configuration abandoned for a straight single-deck arrangement. Design was oriented toward truck traffic.

Table I summarizes the design and operating attributes of the four designs. Figure 2 is a typical layout sketch for one of the vessels (Design II); a midship section of the same vessel is shown in Figure 3. Figure 4 shows the proposed dock and shore terminal area, and indicates how the "drive-through" arrangement would work.

2. Air Cushion Vehicles.

Three conceptual air-cushion vehicles were considered. Two of the designs represent significant advances in the present size of commercially available ACV's and were designed with single vehicle service in mind. The third design is based on the proposed SRN-4Mk.3, the leading particulars of which are available in the literature. This vessel was aimed at providing a two-vehicle service.

A service speed of 52 knots was based on SRN-4Mk.3 data, assuming an average sea state of 3-5 feet, significant wave height, corresponding to approximately a 20-knot wind. Under calm conditions (5-knot wind, with significant wave height under 2 feet), the vehicles would be capable of cruising at speeds in excess of 60 knots. With significant wave height in the neighborhood of 8 feet, however, operating speeds would be reduced

CONVENTIONAL DISPLACEMENT FERRIES

	DESIGN		
	I 28-KT Single Ship	II 26-KT Two Ship	II-T 21-KT Truck
Length (overall)	725.0'	450.0'	450.0'
Beam	83.0'	83.0'	83.0'
Full Load Draft	16.5'	16.5'	16.5'
Service Speed (knots)	28.5	26.0	21.0
Normal Capacity:			
Autos	248	128	-----
Trucks	22	12	36
Passengers	1036	536	72
Full Load Displacement (longtons)	9737	5308	4563
Cost (Millions \$)			
First Ship	\$34.15	\$23.31	\$19.69
Second Ship	-----	22.47	18.92
Annual Operating Cost	4.39	7.04(a)	4.62(a)
Average Annual	8.97	13.17(a)	9.80(a)
Required Fares (\$)			
Passenger	3.89	5.71(a)	4.25(a)
Auto	11.67	17.14(a)	12.75(a)
Truck	40.84	59.98(a)	44.62(a)
			87.82

(a) two ship service

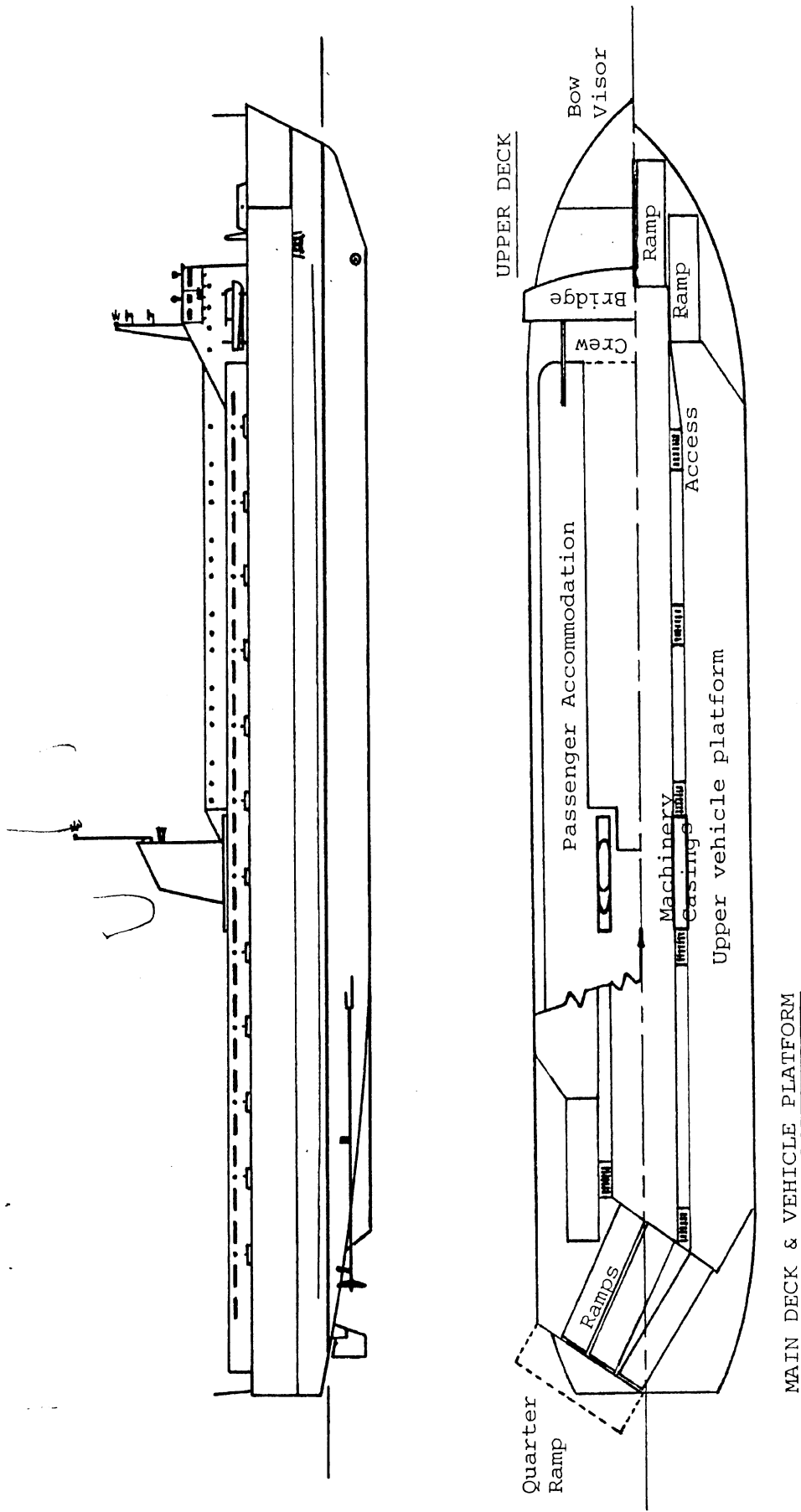


Fig. 2. Outboard profile and general arrangement, Design II. (scale: 1 in = 60 ft).

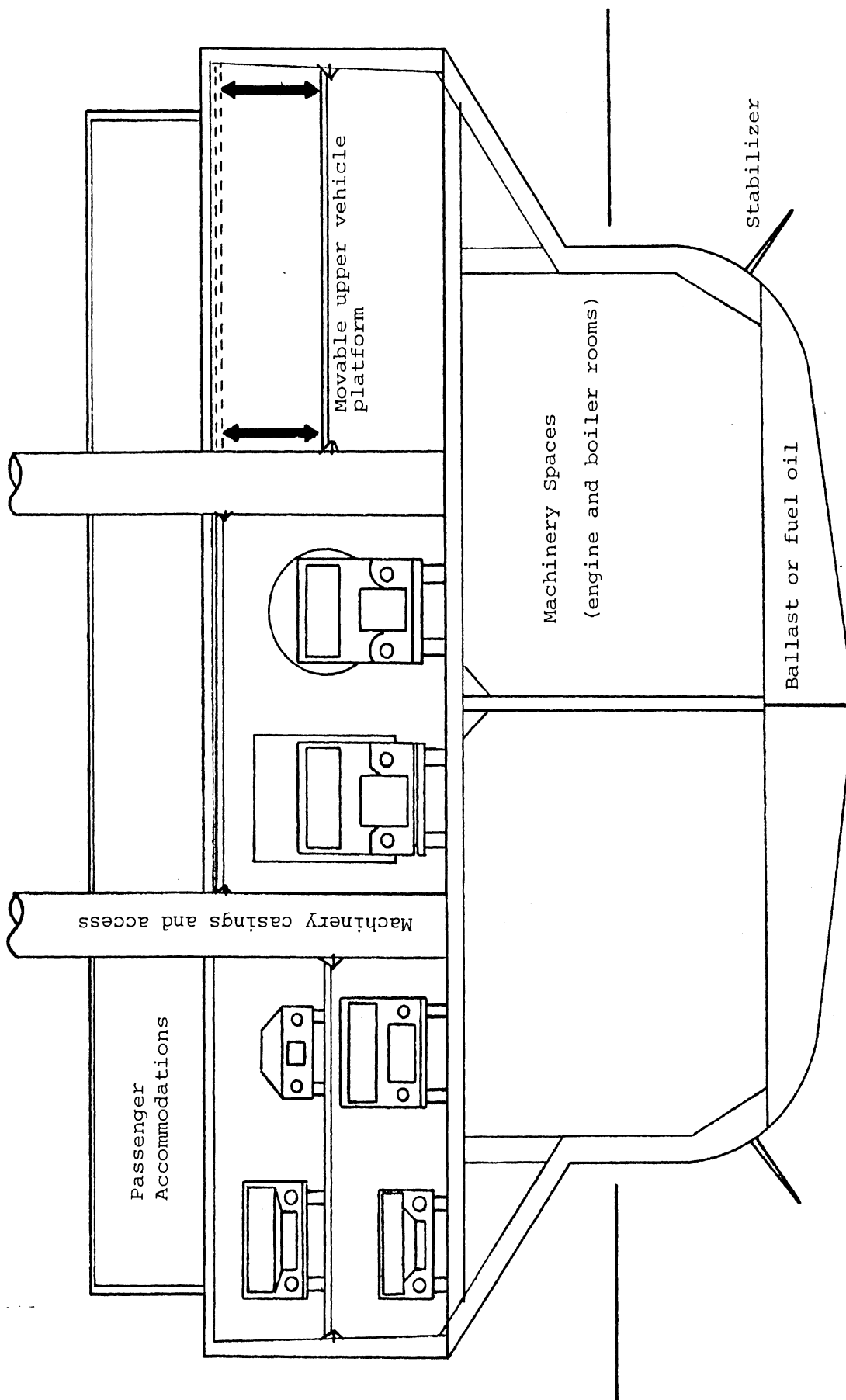


Fig. 3. Midship section (through machinery space), Design II. (scale 1 in = 10 ft).

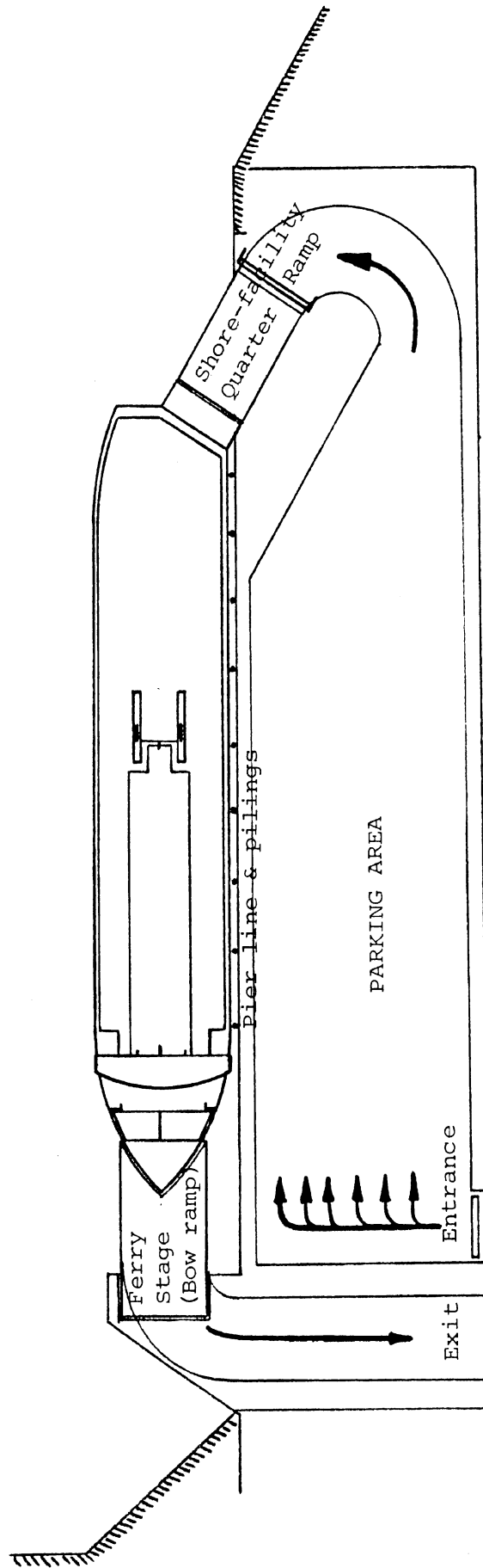


Fig. 4. Typical dock and shore terminal arrangement, Design II. (scale 1 in = 100 ft).

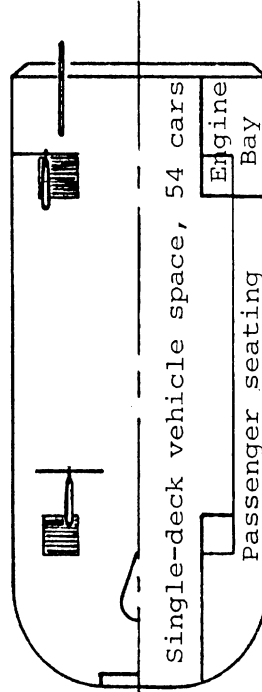
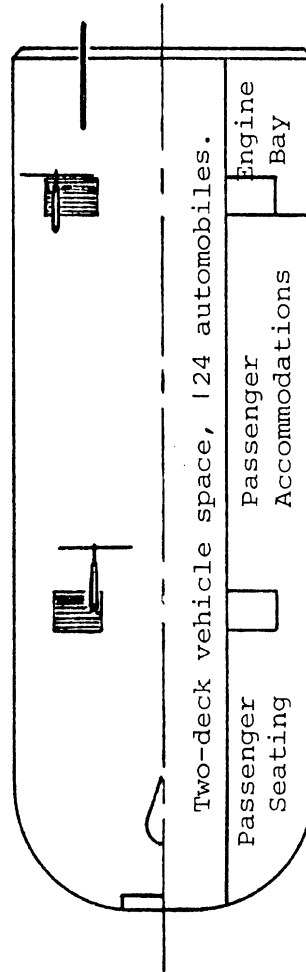
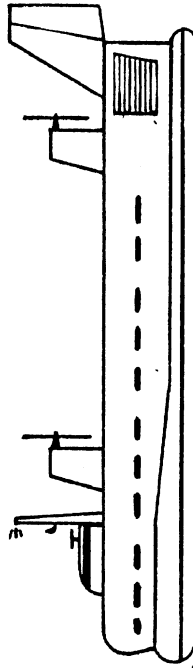
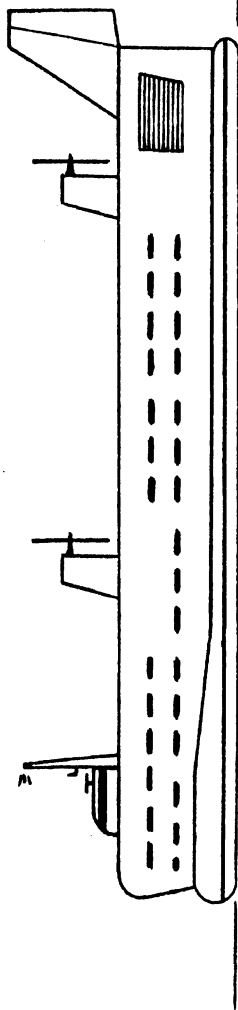
to about 40 knots. Generally, English Channel operations, based on the smaller SRN-4Mk.1, are subject to cancellation under a mean wind speed of 30-35 knots, with an associated significant wave height of 8-10 feet. There is little question that the SRN-4Mk.3, not to mention the still larger conceptual designs, would possess superior operability.

From the standpoint of this preliminary work, a 345-day operating season for ACV's appears to be a reasonable assumption. It is felt that any additional weather days would be compensated by supposed reductions in ice delay days. Speed reductions in ice would result, not from increased resistance, but rather from operational considerations: first, the necessity to avoid skirt damage due to impact with rough or broken ice; second, the requirement for increased margins for slowing and maneuvering.

With regard to vehicle spaces, the smaller ACV was able to carry its full capacity of automobiles on a single deck. The larger craft, Design B, in order to obtain slightly more than double this capacity while remaining within credible overall dimensions and weights, was conceived as a two-deck configuration. In both cases, the major components interrupting the vehicle spaces were the engine compartments and lift fan ducts. The placement of these components tends to divide the arrangement into an in-board space for vehicles, with passenger spaces outboard. Nevertheless, it should be possible to maintain straight-through vehicle lanes.

Passenger accommodations are restricted to fully enclosed spaces, port and starboard, with a single deck on the smaller vessel, and two decks on the larger. These spaces are envisioned as full length passenger lounges, fitted with aircraft-type reclining seats. A limited amount of clear deck space is available, but in general, passengers would probably spend the majority of the transit time in their seats.

General arrangement sketches of the two ACV's, designs B and C, are shown in Figure 5.



ACV DESIGN B: 1-ship service.

ACV DESIGN C: 2-ship service.

Fig. 5. Profiles and general arrangements, air-cushion vehicles Designs B and C. (scale: 1 in = 60 ft.)

Table 2 summarizes the design and operating particulars for those ACV concepts that were evaluated.

3. Comparison of Performance.

Table 3 compares the economic performance of three different concepts ~~the~~ economic performance of three different concepts over a typical route, with two ships operating in each service. This comparison, and other factors described earlier, reveals the following advantages and disadvantages of conventional vessels and air cushion vehicles:

<u>Characteristic</u>	<u>Superiority</u>
vehicle transit time	ACV
schedule convenience and frequency of service	ACV
reliability of service	probably conventional
passenger comfort	probably conventional
attractiveness and convenience of passenger space	conventional
price of service (required fare)	conventional
flexibility of cargo	conventional
flexibility of routing	ACV
cost of shore facilities	ACV
fuel economics	low-speed conventional
novelty and intangible appeal	ACV

Clearly, the above list of characteristics should not be interpreted as a basis for selecting the superior concept, nor can the results shown in Table 3 be so construed. The fact is that air-cushion vehicles and conventional types can be applied with advantages depending on the nature of the market. Any attempt to discriminate between the two concepts, in the hopes of determining the overall superior type, would be premature at this stage.

It is felt that further market analysis is essential. In the interim, it

TABLE 2. DESIGN AND OPERATING PARTICULARS
THREE AIR CUSHION VEHICLES FOR LAKE MICHIGAN FERRIES

	<u>DESIGN "A"</u>	<u>DESIGN "B"</u>	<u>DESIGN "C"</u>
<u>DESIGN ATTRIBUTES</u>			
Dimensions (ft.)			
length	202.5	255.0	185.4
breadth	90.0	95.0	82.0
cushion height	14.0	14.0	14.0
Capacities			
autos	108.0	124.0	54.0
passengers	432.0	496.0	216.0
Estimated Weight (longtons)			
payload	215.0	247.0	108.0
maximum gross weight	607.0	697.0	289.0
Speed (knots)	52.0	52.0	52.0
<u>OPERATING COSTS</u>			
Estimated Purchase Price (\$ million)	not considered	\$35.0	\$20.0
Annual Capital Recovery		5.78	3.30
Average Annual Operating Costs (4 round trips/day) (\$ million)		1.11	1.25
Total Average Annual Costs		6.89	4.55
Required Passenger Fares (\$)			
passenger		5.86	6.60
auto		17.58	19.79

TABLE 3. Comparative economic performance of highway-vehicle and passenger ferry concepts. Transit distance: 60 statute miles. Nominal operating day limitations: 12 hours. All services: two-ships.

Vessel type	High Speed Conv.	Low Speed Conv.	Air Cushion Vehicle
Design	<u>II</u>	<u>IIS</u>	<u>B</u>
Service speed (knots)	26.0	21.0	52.0
Service speed (mph)	29.9	24.2	59.9
Operating days per year	345	345	345
Annual transport volume:			
Automobiles	300000	300000	298080
Trucks	30000	30000	0
Passengers	1000000	1000000	1000000
Required fares:			
Passenger	5.71	4.25	6.60
Automobile	17.14	12.75	19.79
Truck	59.98	44.62	-
Service frequency:			
Sailings per day (each way)	4	4	8
Time between sailings (hr)	3.00	3.50	1.67
First daily departure	9:00 am	8:00 am	8:30 am
Last daily arrival	8:00 pm	9:00 pm	10:10 pm
Vehicle transit time (hr)	3.67	4.14	2.00

can be concluded that various technologies exist, each of which offers some promising solutions to the problem of establishing and maintaining an attractive and competitive cross-lake passenger and vehicle ferry service.

B. Rail Service.

Two operating systems were designed to serve the cross-lake rail link: one based on a single conventional vessel, the other based on a barge-swapping arrangement including three barges and a single tug. A summary of the design and operating particulars is found in Table 4.

The faster turnaround of the tug-barge system permits a significant increase in transits per day, therefore allowing a smaller vessel to serve the same specified traffic volume. In addition, the swap-barge capability permits a single yard-crew shift to unload and load a waiting barge. The tug, on its next return, could then couple up to this loaded barge, and leave a loaded barge to await the next morning's yard shift. By comparison, the conventional ship must have a yard crew in attendance if it is to turn around at all, at least under the present labor setup.

General arrangements and profiles of the conventional rail ferries are shown in Figure 6. As presently conceived, the vessels would be fully covered, 6-rail arrangement, and would unload and load through the bows. (The ITB, obviously, must unload through the bow, if the tug is to uncouple easily.)

The conventional vessel is barge-like in form, with engines aft and bridge forward. Single-screw diesel power was selected without a detailed comparison with steam. Bow and stern thrusters were fitted, in an effort to reduce port and maneuvering delays to a minimum.

Port maneuvering and docking times were considered to be equal for both alternatives, estimated as 20 minutes per call. (Each barge was fitted with a new bow thruster, and in combination with a twin-screw tug, it was

TABLE 4. DESIGN AND OPERATING PARTICULARS FOR TWO RAIL CAR FERRY DESIGNS.

	Conventional <u>Vessel</u>	Integrated <u>Tug-Barge</u>
Dimensions (ft.)		
overall length	450.0	430.0
barge beam or vessel beam	78.0	78.0
full-load draft	16.5	----
barge draft	----	10.0
tug draft	----	15.0
Capacities		
railcars	38.0	30.0
Speed (knots)	16.0	16.0
Costs (Millions \$)		
first unit price	16.3	3.98
second unit price	----	3.81
third unit price	----	3.66
tug cost	----	6.50
linkage cost	<u>----</u>	<u>1.00</u>
total system	16.3	18.95
annual operating costs	1.89	2.15
annual capital recovery cost	<u>2.19</u>	<u>2.54</u>
total average cost, annual	4.08	4.69

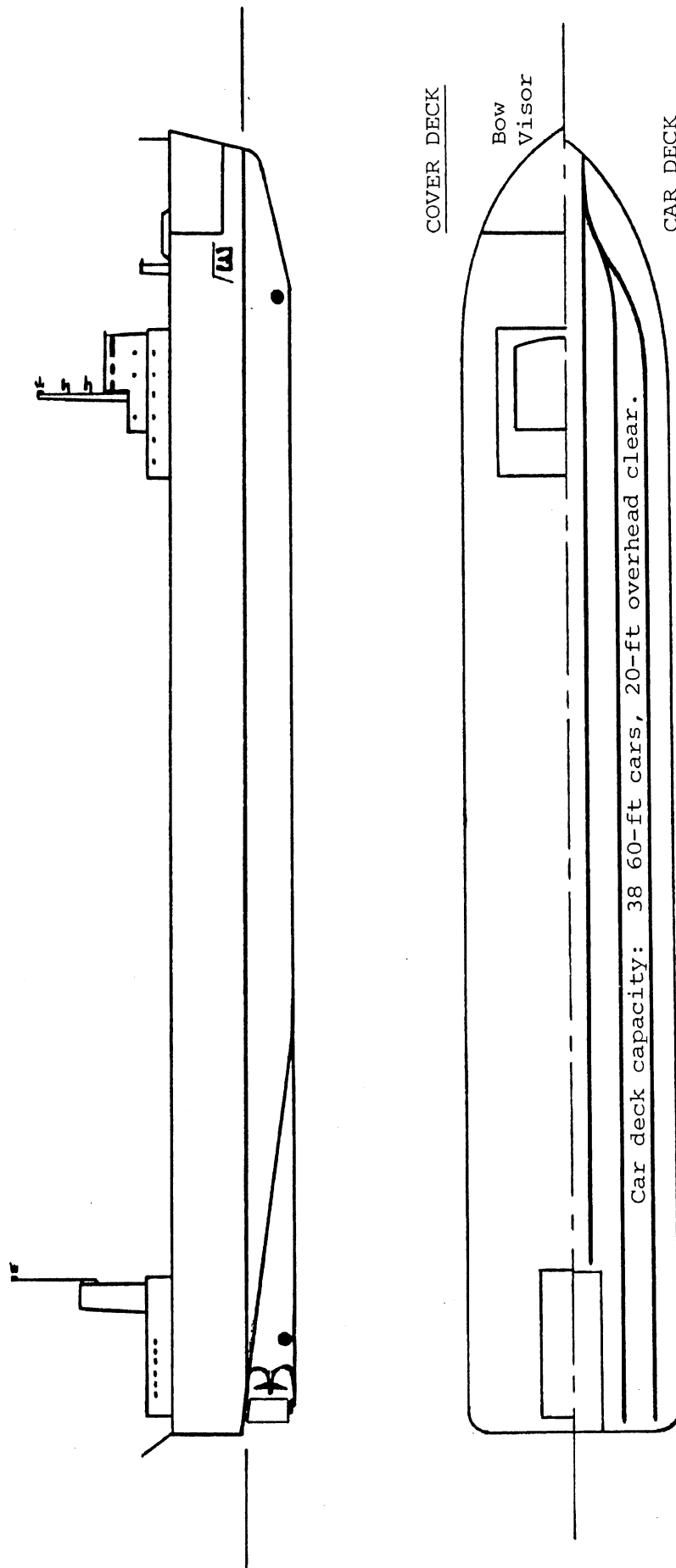


Fig. 6. Profile and general arrangement, rail ferry conventional vessel (scale: 1 in = 60 ft.)

felt that the ITB combination could match the maneuverability of the conventional vessel. An additional 60 minutes of port delay per call was exacted for wire operations only.)

Car-securing operations were assumed to be performed by ship's crew, in the case of the conventional vessel, and by yard crew in the case of the ITB system. Loading and unloading delays were estimated at 90 minutes for the conventional vessel, perhaps unjustly long, but assuming a single switching locomotive assigned. (The delay might be cut in half by assigning twice the locomotive and man-power, but the economics of this decision will not be considered without further data.) The ITB combination was not delayed by cargo-handling operations, apart from the barge-swapping time mentioned previously.

An economic comparison of the two systems with the M.S. Viking is shown in Table 5. This table shows that there would be some differences in the operating costs. The ITB, especially, shows definite promise of having operating efficiencies that will permit cost savings. These data are initial estimates, however, and it is probable that with more definitive examination, further economies (or costs) would be identified.

ALTERNATIVES ACROSS LAKE MICHIGAN

	<u>M.S. Viking (Existing Ship)</u>	<u>New Design Motor Ship</u>	<u>Integrated Tug Barge</u>	
			<u>One Barge</u>	<u>Three Barge</u>
Operating Costs (Million \$/year)	2.06 ⁽¹⁾	1.8	1.7	2.2
Capital Costs (Million \$/year)	<u>.19⁽²⁾</u>	<u>2.2</u>	<u>1.5</u>	<u>2.5</u>
Total, Average Annual Costs (Million \$/year)	<u>\$2.25</u>	<u>\$4.0</u>	<u>\$3.2</u>	<u>\$4.7</u>
Transits Per Day	3.8 (avg.)	4.0	4.58	6.0
Car Movements Per Year (330 day/year operation @ 100% capacity)	26,000	50,000	45,300	59,400
Cost/Car (\$)	\$87	\$80	\$70	\$79

(1) Based on 1974 data in A.T. Kearney study, multiplied by 50% to allow for increased fuel costs and other inflationary factors.

(2) Based on 1974 data in V.M. Mulanaphy 1975 report.

IV. CONCLUSIONS AND RECOMMENDATIONS.

A. Conclusions.

Early analyses indicated that if ferry service is separated, there are alternative designs that would be attractive options.

In a ferry service designed to handle only passengers and passenger vehicles, the air cushion vehicle has unusual potential. The ACV is a high speed system, capable of making a lake crossing in less than one hour. Additionally, it only needs a ramp at its port terminals, making it feasible to operate without restriction into any port facility on the lake. Such an attribute would make it possible to respond, at will, to almost any cross-lake transit need. And, finally, the fare requirements for this type of service is competitive with that presently being charged.

A two-ship, moderate-speed (21-knot) conventional design ferry also would have several attractive features. First, the required fare rates would be significantly under those currently being charged. As was shown in Table 1, the necessary fares would be:

passengers	\$4.25
automobile	12.75
truck	44.62

And, importantly, the time-between-sailings would be only 3½ hours, which is a major reduction from that currently existing.

There would also be merit in a design especially tailored for truck trailers. The integrated tug-barge is one possibility, and the economics are such that trailers could be moved at a rate which is significantly less than around-the-lake costs. The conventional ship design would also be attractive if it is not appropriate to ship only the trailers, or if the demand is such that truck trailers could not be accommodated in combination with passenger vehicles.

The most attractive alternative design for a rail car ferry service is the ITB. The system, on first analysis, appears to offer economies over the present service if car movements of about 45,000/year can be maintained. The break-even point against the existing system would occur at about 37,000 car movements per year.

In any evaluation of rail car ferry economics, it should be remembered that institutional factors are the major determinants of profitability. The volume of car movements, for example, is more directly related to internal railroad management practices than to costs of ferry operation.

B. Recommendations.

The study recommendations are divided into three general categories:

(1) development of more definitive ship design concepts and costs, (2) market demand analyses, and (3) analyses of organizational concepts appropriate to expanded ferry service.

1. Development of More Definitive Ship Designs.

Four designs, especially, merit more definitive analysis for further refinement of costs and performance. They are:

- 26-knot conventional vessel (Design II)
- 21-knot conventional vessel (Design IIS)
- air cushion vehicle (Design C)
- integrated tug-barge

Included in the above analyses should be definitive evaluations of port facility modification costs and operating costs.

2. Market Demand Analysis.

There should be a market demand analysis undertaken to confirm the extent of market potential for ferry services across Lake Michigan. This analysis should indicate market needs for each of the segments (e.g., passenger,

truck, rail etc.) and the demand/cost elasticity relationships for each segment. In the segment analysis, it would be beneficial if it were possible to differentiate between truck-trailer combinations, and trailers only.

3. Analysis of Organizational Concepts.

It is believed appropriate that investigations be initiated that will evaluate benefits (and costs) to the State resulting from various organizational forms of an expanded ferry service. Included in this analysis will be factors of ownership, sources of capital, and management structure. The analysis should be sufficiently detailed to provide guidance for any type of expanded ferry service recommended.

